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Presidential Address - Some Features of the Science of a Hundred Years Ago

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Hendrixson: Presidential Address - Some Features of the Science of a Hundred

PRESIDENTIAL ADDRESS.

SOME FEATURES OF THE SCIENCE OF A HUNDRED YEARS AGO.

BY W. S. HENDRIXSON.

In the past three or four years the popular magazines have contained numerous articles on the progress of science in the nineteenth century. These papers were written for popular information and they deal with only a few great discoveries with which all men of science are familiar. It occurred to the writer that for the entertainment and information of the man of science, who is acquainted with the main facts and theories of every science as it is to-day, and who, though not acquainted with its minute details, is at least aware of its great mass of facts, its intricate theory, and ponderous and ever increasing literature, it would be more to the point to define the conditions of science as it was at the beginning of the century, and let him arrive at a conception of its progress by subtraction.

Upon actual trial I found the process fascinating in more ways than one, and it occurred to me that it might be interesting to us to-day to look back 100 years, or about the extreme limit of a human life, pay our respects to some of the worthies of that day, take a view of their science and contrast it with our own.

It seems wise to restrict our attention to the universally recognized natural sciences, and indeed to those that furnish topics for discussion in this body: Chemistry, physics, biology and geology.

It will be necessary, and we hope interesting, to trace each of these sciences from its birth, so nearly as that date can be determined, down to the even date 1800, or 100 years ago, giving dates of important discoveries both in fact and theory. There must always be uncertainty regarding the dates of many discoveries. To cite examples, we may trace an atomic theory and a

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theory of evolution back to the time of the early Greek philosophers, yet neither assumed a scientific form until about the beginning of this century. In these and all similar cases the speculations of philosophers, suggestive though they have been, will be passed over and the origin of theories placed at the times when they arose as the results of true scientific research.

It is assumed that there is no occasion in this presence to explain any prominent fact or theory of science farther than to mention it by name.

CHEMISTRY.

The phenomena of Chemistry that appeal to ordinary observation are not many, and the factors of chemical reactions lie beyond the reach of the senses. This may account for the fact that scientific chemistry is a matter of recent origin. Its beginning as an empirical art probably antedates authentic history, but as a science it is difficult for one of the present time to conceive of its existence prior to the discovery of oxygen by Priestley in 1774, and the explanation of the relation of this most important element to combustion and calcination by Lavoisier from about 1777–1783.

The history of Chemistry down to Lavoisier is, as regards theory, a long night with only here and there small gleams of light due to the illumination of the torch of a Boyle in the seventeenth, and a Black in the eighteenth century. The former clearly distinguished elements and compounds, and gave the beginnings of a theory of chemical reaction; but his good work was lost sight of, and completely disappeared with the rise of the theory of phlogiston by Stahl, in the seventeenth century. This theory has such an important relation to the material theories of light and heat that a word of explanation is necessary. It assumed a fire principle which escaped in the combustion and calcination of bodies. A calx, or oxide in our language, was, therefore, an element, while a metal was due to the union of a calx with phlogiston. The more violently a body burned the richer it was in phlogiston, the gaseous products of combustion seeming to be ignored. Later in the history of the theory, carbon, sulphur and hydrogen were successively identified with phlogiston. At first no account was taken of the increase of weight when a metal changed to a calx. Later when hard pressed upon this point phlogistonists did not hesitate to ascribe to phlogiston the property of negative gravity or levity. During this period of theory gone utterly wrong, facts were accumulated by the investigation of many able men, and these were soon to serve a purpose in the establishment of a new theory by which they also were to be co-ordinated and explained.

The work of Lavoisier marks an epoch in chemical history, and paves the way for a general theory. He first employed the balance systematically, and clearly showed that calcination and combustion were processes of union of oxygen with other substances, and his work marks the overthrow of phlogiston. There arose again with his work true ideas of element, compound and chemical reaction.

Probably most chemists accustomed to use the atomic theory with as much confidence as the carpenter uses his square and pencil in marking out his work, would place the origin of *scientific* chemistry at the announcement of the rudiments of the atomic theory by John Dalton, in 1803. This theory was the outgrowth of the law of definite proportions demonstrated by Proust, 1799–1807, against the determined opposition of Berthellot and his school, who argued that the constitution of one and the same compound is variable, and the law of multiple proportions discovered by Dalton himself. The theory accounts for these laws; it is, therefore, the result of legitimate scientific work, and is not to be confused with the speculative theory of atoms of the Greeks. That Chemistry passed the date 1800 without an atomic theory of any kind, sufficiently indicates its condition. No further comment is necessary.

To this period belongs the discovery of nitrogen, phosphorus, chlorine, hydrogen, oxygen, manganese, cobalt, nickel, platinum, though they were not regarded as elements, and many of their compounds were made; the distinction between caustic and mild alkalies, and the relations of acids, bases and salts, were pointed out; many new gases were studied and the foundations of analysis were laid. To this period belongs a long array of illustrious names—Black, Cavendish, Priestley, Galen, Scheele, Hales, Mayow, Bergman and Hoffmann, who paved the way for Lavoisier and Dalton. The theory of phlogiston, though wrong, served to explain and group certain related phenomena, and to that extent there was science of chemistry.

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PHYSICS.

So many physical phenomena are met in daily life that it is no matter of surprise that many elementary principles of Physics have been understood for centuries. It is probable, however, that most physicists would place the beginning of scientific physics at about the time of Galileo. He has justly been called the Father of Physics. It is surprising how many great discoveries were made by this many-sided man. It was he who discovered the law of falling bodies, the path of projectiles, the laws of the pendulum, the parallelogram of forces, the satellites of Jupiter, sun-spots and the rotation of the sun upon its axis. He was the first to demonstrate that the air has weight. He greatly improved if he did not invent the telescope and seems to be the first who used it to observe the heavenly bodies. He invented in 1593 the thermoscope consisting of a bulb and stem, the latter partly filled with water and ending in water. It was his pupil Torricelli who devised the barometer and used it to measure the fluctuations in the pressure of the air. About the same time, or about the middle of the seventeenth century, Von Guericke invented the air pump, and a few years later Boyle discovered the important law that the volume of a gas varies inversely as the pressure.

It will be necessary to trace very briefly the progress of discovery in at least three branches of Physics: Light, heat, Electricity and Magnetism.

LIGHT.

The law of reflection of light could scarcely escape the earliest observers and was known to the Greeks. But one must come down to the early part of the seventeenth century for any further advance in the knowledge of light. It is here we meet the invention of the telescope and the microscope in crude forms. It may seem strange that they were invented without a knowledge of the law of refraction, which was experimentally discovered by Snell about 1620, and was given its present form by Descartes in 1637. It was in 1676 that Roemer determined approximately the velocity of light, which before that time was believed to be infinite, from the eclipse of one of the moons of Jupiter, and in 1728 his theory was confirmed by Bradly, who made a nearer approximation in the determination of its velocity; for any advance in this direction we must come down to the middle of the nineteenth century.

In 1665 Robert Hooke suggested a wave theory of light, and such a theory was elaborated by Huygens in a paper before the French Academy in 1678. He assumed the existence of an all pervading ether. He described the double refraction in Iceland spar and observed that both rays were polarized. But polarization received little further attention until the time of Young and Fresnel in our century. The wave theory met the determined opposition of Newton, whose great and increasing authority caused it to sink out of sight for more than 100 years, when it was again brought into prominence by Young in 1801, and was finally established by the experiments of Foucault and Fizeau on the velocity of light in 1850. Though a supporter of the corpuscular theory of light chiefly because it explained the propagation of light in straight lines, Newton made several important additions to our knowledge of light, and probably failed to discover the spectroscope only because the beam of light that fell upon his prism came through a round hole instead of a slot parallel to the edge of his prism. He was the first to explain dispersion upon difference of refrangibility of the rays. He believed that it was not possible to make an achromatic lens and, therefore turned his attention to a reflecting telescope which he invented in 1668.

The phenomenon of diffraction was discovered by Grimaldi in 1666 and experimented upon by Newton, but like polarization it had to wait for its explanation until 1815, when Fresnel r discovered the phenomenon. The eighteenth century witnessed little progress in light beyond the construction of achromatic lenses by Dolland in 1758, and their application to the telescope and microscope.

HEAT.

The first thermometer was invented by Jean Rey, in 1632, by inverting the thermoscope of Galileo and filling the bulb and part of the stem with water. Twenty-five years later the end of the bulb was sealed, and alcohol replaced the water. Mercury was first used in 1659. The thermometer was perfected and the present fixed points adopted by Fahrenheit in 1724, and Celsius in 1742. The discovery that liquids have definite boiling points is apparently due to the former.

The ideas of specific heat and latent heat, apparently originated with Joseph Black in 1756, and he determined the latent heat of vaporization of water and liquifaction of ice. The

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ideas of Black soon bore fruit in the improvement of the steam engine by Watt, in 1783. Lavoisier determined the specific heat of a number of substances.

The mechanical theory of heat was not known to the philosophers and scientists before the eighteenth century. From a speculative point of view, Descartes, Boyle, Bacon, Hooke and Newton all looked upon heat as possibly a mode of motion. Boyle actually experimented upon the mechanical production of heat, but the theory never attained a scientific basis until the nineteenth century, and, in fact, was not established beyond controversy until about the middle of our century.

The material theory of heat can be traced to the Greeks. In the early part of the seventeenth century it was advocated by Gassendi; the phlogiston theory of combustion seemed to lend it support. In 1783 the French Academy offered a prize for the best paper on the theory of heat. It was won by Euler, who supported the material view, though he is apparently the only man of the century seriously to advocate the wave theory of light.

The material theory was not seriously questioned until Count Rumford observed the enormous amount of heat caused by friction, in boring cannon at Munich, in 1798. He surrounded a piece of brass, in a cavity of which worked a blunt drill, with a box in which he placed eighteen and one-half pounds of water. The drill was started in rotation and at the end of two and one-half hours the water actually boiled. He expresses his delight, and the astonishment of the bystanders, that so much water should be made to boil without any fire. He remarks that the source of heat generated by friction seems inexhaustible. In 1804 he wro e to Pictet, of Geneva, "I am persuaded that I shall live a sufficiently long time to have the satisfaction of seeing caloric interred with phlogiston in the same tomb." But Rumford underestimated the strength of conservatism. The war over the nature of heat was to be a long one, and the establishment of the mechanical theory required fifty years, and all the genius of Young, Meyer, Joule, Thompson, Carnot, Clausius and Rankine.

ELECTRICITY AND MAGNETISM.

Electricity and Magnetism may be considered together though their relation was discovered by accident by Oersted in 1819. The facts of the existence of magnetism and electricity have been known for ages. The founding of magnetism as a branch of science may be placed in 1600, when Gilbert published his "De Magnete." He was the first to use the terms magnetic force, pole. He first studied the declination of the magnetic needle, and first asserted that the earth is itself a great magnet. Magnetic charts were made about the end of the century. There is probably no branch of science that made such progress in the eighteenth century as electrostatics. It is very largely a product of that century. The frictional electric machine of Von Guericke of the seventeenth century consisting of a revolving ball of sulphur rubbed by the hands, was gradually improved by the substitution of a glass globe, then a glass cylinder, and finally a glass plate for the sulphur ball, and fixed pads with amalgam finally took the place of the hands.

Stephen Gray electrified the human body in 1730. Du Fay repeated Gray's experiment and finally arrived at the conclusion that all bodies may be electrified, and he discovered that there are two kinds of electricity. The Leyden jar came in 1745–46 and created no end of interest. There followed soon the ideas of insulation, induction, and potential. The influence of points in dissipating the electric charge was dwelt upon by Franklin, who studied atmospheric electricity, arriving at the identity of electricity and lightning, and suggested the protection of buildings by pointed rods.

In 1747 Franklin advocated a one fluid theory. A body having a certain charge was neutral; less than this amount gave the effects called negative; more gave the effects associated with positive electricity.

The latter half of the century saw great advances in electric measurements. Cavendish, the recluse, studied electrical measurement and before 1771 arrived at clear conceptions of inductive capacity and constructed a set of condensers, and determined the capacity of several substances. He proved that static charges are on the outside of hollow bodies, that electric force varies inversely as the square of the distance, but his writings were not made public for a century.

Coulomb invented the torsion balance, and proved that the force of electric attraction or repulsion varies inversely as the square of the distance, and as the product of the quantities of the electricities. He showed that electric charges reside on the surface of bodies, and revived the two fluid theory of Du Fay.

On November 6, 1780, was made the famous discovery by Galvani of the influence of electricity upon a recently killed frog, leading to the production of the electric current by the contact of dissimilar metals, which, in turn, led to the invention of the electric pile and the crown of cups by Volta in 1800. The beginning of dynamic electricity is to be placed here, and this branch of electricity, which has made such unparalleled advancement in our century and has been so profoundly influential in both the thoughts and the material affairs of men, is, therefore, a product of the last 100 years. The change in the condition of electrical science during the last 100 years is typical of that of the whole science of physics, and I might even say of all science, and our conception of the world. The change is one of statics to dynamics. Up to 1800 there was no wave theory of light, no polarization, no spectroscope. There was no mechanical theory of heat or thermo-dynamics, no transformation of energy, and no dynamic electricity.

Physics is regarded to-day as essentially a quantitative science, and yet 100 years ago very few measurements of any sort had been made, and in the huge mass of our present constants I find none that have come down to us from the last century.

BIOLOGY.

Historically the development of Botany and Zoology show such close parallelism that for present purposes they may be considered together under the name Biology, which was really coined in our own century.

Though good beginnings in the anatomy and physiology of both plants and animals were made before 1800, the attention of botanists and zoologists was mainly directed to the work of systematizing, and here the most marked advancement was made. As a systematizer in the animal, vegetable and mineral kingdoms, Linnaeus stands preëminent. He invented a new vocabulary of descriptive terms, and gave us our binomial system for the designation of species. In his systems the accumulated facts of Natural History found a convenient, simple, orderly and exact arrangement, and there followed a great impetus in the discovery and description of new forms, probably to the neglect of other and, as we now regard them, more important branches of the science. The systems of Linnaeus were confessedly artificial. Holding as he did the idea of the fixity of species which was a prime article of faith of most biologists, even down to nearly the middle of our century, he could not conceive of a natural system as we understand it in the light of evolution. To him a natural system was a thing of the future, and it would represent the plan of the Creator. His systems were predominent to about the end of the century, when they were succeeded by others, framed in the attempt to form a natural system, and to provide place for the enormously increasing numbers of known plants and animals of the lower orders. Most of the elements of our present biology had a vigorous beginning in the seventeenth century, but little advance was made during the eighteenth century, and this was mainly due to two causes: the influence of Linnaeus that turned the attention of men to classification, and the tendency toward excessive speculation in the eighteenth century, observable in the history of all sciences, and having its foundation in the general belief that a System of Nature was something to be thought out by *a priori* reasoning.

The first man to observe vegetable cells was probably Robert Hooke, in 1667, not as a botanist, but as one interested in showing the power of the microscope. The first to study in a broad way the minute anatomy of plants, and to describe the structure of plant and animal tissues, were Malphigi and Grew, 1670–82. They did not, however, regard the cell as the unit of plant and animal structure, or from a cell theory. Beyond some work by Wolff, in 1759, who attempted to found a cell theory, little was added to the work of Malphigi and Grew until 1801, when the subject was taken up by Mirbel. The first cell theory wo·thy of the name was proposed by Schleiden, according to which the cell is the unit of all plant tissue; and in 1838 the theory was applied to animals, by Schwann. The physiology of the cell, in essentially its present form, was given by Nägeli, only after protoplasm was investigated by Von Mohl, in 1846, and Schultze and De Barry recognized it as the essential part of the cell. The essentials of our theory of the origin of tissues and their classification were worked out between 1820 and 1860.

The history in time of the theory of reproduction is long and interesting, both from the scientific and the psychological point of view. Strange as it may seem the fact of sexuality in plants was first definitely asserted and scientifically maintained by Comerarius about 1694, but his work was lost sight of until republished 100 years later. Despite the seemingly decisive experiments on close and cross fertilization by Gleditsch about the middle of the century, and the thorough and wide reaching experiments of Koelreuter, from 1761–1766, who produced hybrids by cross fertilization, the question of the sexuality of plants continued a matter of dispute until finally settled by Gärtner, who collected the evidence from the work of his predecessors, added it to his own results of experiments extending over twenty-five years and combined all in a volume published in 1849.

The study of the fact of sexuality necessarily involved the study of the functions of the pollen and ovule in fertilization, and here again there was much controversy among those who accepted sexuality, which ended so far as flowering plants are concerned with the discovery of the descent of the pollen tube and its influence upon the egg-cell, by Amici in 1846. The reproduction of the cryptogams was generally thought to be a sexual.

In 1657 Harvey, the discoverer of the circulation of the blood, declared that all living things come from an ovum by differentiation, and that the ovum might proceed from parents or arise spontaneously. Twenty years later, Hamen discovered the spermatazoa, which he regarded as the young, which required only to be nourished by the ovum. Here we have two theories of reproduction that were at war for more than a century and a half.

Wolff, who first studied the development of the chick under the microscope, described the blastoderm in 1759, and its differentiation into organs, contrary to the general opinion held by Grew, Buffon and Haller that the embryo was a complete being like the bud of a tree, whose growth was merely an unfolding. It was in 1827 that Von Baer discovered the ovum of mammals, traced its development and laid the foundation of Embryology.

The seventeenth century saw good beginnings in histology and Comparative Anatomy of animals. Malphigi studied the anatomy of insects; Leuwenhoek discovered striated muscle-fiber and epidermal cells. Swammerdam studied the anatomy of insects, molluscs and the metamorphosis of insects. It may be said, however, that in the eighteenth century such studies were largely superseded as in Botany by classification, and were not again seriously taken up until the rise of Comparative Anatomy with Lamarck, St. Hilaire, Meckel and Cuvier.

Of the nutrition of plants and animals the previous centuries have little to say. Malphigi inferred that the food of plants was elaborated in the green parts. Mariotte showed that plants form chemical combinations from food material taken from the earth and air. Little more could be done before the discovery of oxygen in 1774, and the explanation of the movement of sap had to wait for the discovery of Osmosis in 1822. Relying upon the work of Lavoisier, who himself experimented upon the respiration of plants and animals. Ingen-Houss proved in 1796 that all parts of the plant absorb oxygen and form carbon dioxide, but that the green parts under the influence of sunlight absorb carbon dioxide and exhale oxygen. De Saussaure and Liebig have both been regarded as the founders of this branch of physiology, but they both belong in a later period. It need hardly be stated that animal nutrition was a subject far too difficult for the time.

Probably the greatest doctrine of all science after that of gravitation is Evolution. The idea in some form may be traced to the early Greeks, and it has a place in the discussions of most modern philosophers. It was prominently brought forward, but as a speculation by at least two men of science of the eighteenth century, Buffon and Erasmus Darwin. With neither, however, did the idea advance beyond conjecture or suggestion, and neither seems to have attempted to establish it either by *a priori* reasoning, or by the marshalling of facts; and the great majority of biologists, therefore, place the origin of the idea as a scientific doctrine at the time of the publication of Lamarck's Scientific Zoology in 1809.

To sum up, therefore, we have previously to 1800, a biology of classification, chiefly in the higher orders of plants and animals. We have the beginnings of minute anatomy, the beginnings of theories of reproduction, nutrition and evolution, and the idea of homology as a speculation by Goethe. There was yet no evolution so far as regards its factors, variation, external influences, heredity; no variation or origin of species in time; no movement and, therefore, properly speaking, no scientifically founded Philosophy of Biology.

GEOLOGY.

Geology is a composite of many sciences, and the history of its development is exceedingly complex. Its principles do not admit of ready demonstration by formal syllogisms and Q. E.

D's. Its present conceptions are due to careful balancing of ever accumulating evidence. In probably no other science has there been so much shifting of opinion, and none can vie with it in the amount of wreckage of abandoned theory.

In the short five minutes at command, no more can be done than to state the condition of the science one hundred years ago as regards the cardinal features, the recognition of a geological succession in time, the origin of stratified and unstratified rocks, the significance of fossils, and the development of stratigraphy. We shall have to omit the theories of the natural philosophers, the foremost of whom were Leibnitz and Buffon, regarding the origin of the earth and its inhabitants, suggestive as they were, and proceed at once to the results of scientific research.

According to Geikie, the distinct idea of a geological succession arose with Lehmann, in 1756, as the result of his observations in the Harz mountains and in the Erzgebirge. He classified mountains according to age, and drew sections showing the order of the strata upon their sides, and distinguished between the center of older origin and the fossil-bearing strata. Similar observations were made by Pallas, in Siberia, in 1772–1776, and they were carried further by Fuchsel in his history of the mountains of Thüringen in 1762. He believed that strata had originally been laid down in the bed of the ocean as sediment, and were subsequently displaced or tilted by earthquakes or oscillations of unknown origin. He recognized that different strata have their characteristic fossils, which he regarded as the remains of plants and animals, an opinion by no means general at that time. He inferred that the land was above the sea level during the growth of the plants whose remains he studied. None of these three men seems to have distinguished between the essentially different rocks of the mountains they studied, or to have formed a theory of their origin beyond that they were deposited as sediment from water.

About 1787 there arose to prominence Abraham Gottlob Werner, who, though wrong in his theory and a despot in his opinions, yet by a personality of unusual power, by his systematic arrangement of data and his enthusiasm, gathered about him a large following of devoted students, and ruled the world of geological opinion until near the time of his death in 1817.

Werner went back for part of his theory to Leibnitz and Buffon. The two foundation principles of his doctrine were, first, that originally the ocean was as deep as the tallest mountains are high, and that all rock we call igneous or primary, including granites, gneiss and basalt, were due to chemical precipitation from water. Later rocks, including some shales and limestone, were due chiefly to precipitation, but partly to sediment; and lastly, rocks formed chiefly of sediment, including upper limestone, sandstone, coal, clays, loam, etc. During this time the universal ocean continually subsided, but where the water went to was never explained. He seems to have had no conception of subsidence or elevation of the land. Secondly, he held that there were universal formations represented by those of Saxony, extending over the whole earth. When he announced his theory he had never been out of Saxony. It was, according to him, the province of Geology, or "Geognosy" in his nomenclature, to recognize these formations, and hence to predict the location of minerals in other lands. Werner regarded volcanoes as local phenomena of recent origin, and caused by the combustion of coal. According to him, veins of whatever kind were due to deposits from the quiescent water in cavities or cracks in the rock.

Such was the system that remained predominant until the early years of this century. Its overthrow was due to several causes, among which were the influence of Hutton in England, the impossibility of compressing the formations of other lands, when studied by Werner's pupils, within the "universal formations," and the demonstration of the volcanic origin of basalt. The last was due chiefly to Desmorest, as the result of thirty years' work with the region of extinct volcanoes at Auvergne, France, as a center. His complete account of this region was not published until after the beginning of the century. His conclusions were confirmed by two of Werner's most eminent pupils, Von Buch and D'Aubuisson, who investigated the same region between 1802 and 1804 and publicly announced their change of view.

James Hutton, in 1783–1795, deserves to be called the founder of dynamic geology, though his theory had little influence until explained by Playfair and Hall in 1802. Hutton insisted upon accounting for geological conditions upon the basis of known causes. He studied erosion and advanced the idea that our present world is built up from the fragments of an older world, and perhaps that from one still more ancient. He said, "In the economy of nature I can find no trace of a beginning and no prospect of an end," a conception of the immensity of time that reminds one of Lyell and Darwin. The older continents crumbled away and their fragments were scattered over the floor of the sea. There were periods of convulsion when the land rose and the water receded, but he takes no account of subsidence of the land. Hutton suspected the igneous origin of granite on the theory that the granite had risen in the molten state from the molten interior of the earth. He explored the mountainous regions of Scotland and found numerous instances where granite had intruded the limestone and shale from below.

On the theory of a molten interior he explained foldings, faults, and fractures of strata and accounted for volcanoes. Forty years later his theory, remodeled almost out of recognition and elaborated in the light of accumulated evidence, appeared in Lyell's Principles of Geology.

Though fossils must have attracted the attention of the earliest observers of nature, strange as it may seem to us they were generally regarded as freaks of nature or as forms cast up in the deluge of Noah, until about the middle of the last century. At this time Güttard figured and described some hundreds of them, argued at length that they were the remains of living beings and pointed out their analogy to existing forms.

Fossils were used as an aid in the recognition of strata by Lehmann, Fuchsel, Werner and others, but they were not recognized as the key to stratigraphy until about 1800, and this recognition was due chiefly to William Smith, Cuvier and Brongniart, who are regarded as the founders of stratigraphy.

Smith, who most nearly resembles the modern geologist as we understand the species, began his observations in 1794 while a canal engineer. His first card of the English strata was privately circulated in 1801, and his great map covering the whole of England appeared in 1815. The joint paper of Cuvier and Brongniart appeared in 1808, a year after the founding of the Geological Society of London.

Such are a few of the facts. Before 1800 Geology had no name or habitation, or recognition as a distinct science, but was regarded as a branch of physical geography or mineralogy.

To the layman the Geology of 100 years ago appears as a fragment or a collection of fragments. Magnificent as some of its theories were, they were in the early stages of hypotheses. To make a science more facts were needed, and they would have to be harmonized by a judiciously critical and

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co-ordinating mind. Few formations had been studied and none with thoroughness. There was no arrangement of historical periods, no glacial theory, no scientific petrography, no conception of the vastness of geological time.

Such, in brief, was the history of the great features of our sciences, and such their condition so far as they existed up to one hundred years ago, regarded only as a body of fact and theory. As regards the dissemination of scientific truth, the conditions were even more primitive. A hundred years ago Chemistry had not emerged from the cave or cellar, and the naturalist was looked upon as an uncanny individual of questionable position in the community. Scientific knowledge in those days was mainly confined to savants, and there was little scientific literature outside the proceedings of a few learned scientists. Books for popular instruction, text-books and popular scientific lectures were practically unknown. Systematic instruction in science was given only in a few of the universities, and in this instruction the laboratory played no part. The first laboratory for students in chemistry was that of Liebig, founded in 1824; and the first physical laboratory was founded about 1845. There is no need, in this place, to compare or rather contrast such conditions with those of the present.

It might be interesting, if time permitted, to turn our attention to the influence of science. Omitting its influence in material ways which is as wide as industry itself, let us for a few moments turn our attention to its influence upon thought.

It is chiefly to science that we owe our present democracy of thought. As late as the seventeenth century, men went with profound faith to Aristotle for their science, and his authority was absolute. It was, therefore, a momentous occasion for science when Galileo, one fine morning about the middle of the seventeenth century, before the assembled university, dropped, at the same time, two shot, of one and one hundred pounds weight, from the top of the tower at Pisa, showing that they struck the ground at the same time, and declared that Aristotle was wrong. He went to prison for his rashness. By the authority of Newton, the corpuscular theory of light was fastened upon physics for a century. Since those times men of science have learned to disregard mere opinion. The determined fight of Priestley for phlogiston could not save it, and the opposition of Cuvier and Agassiz to the theory of

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evolution could not stay its progress. Opinions are liable to be wrong, and they are, at best, things of a day. They must be changed in accordance with later developments. If there is one lesson that science has had occasion to learn, it is that of the dynamics of thought, and the evolution of all science. The lesson of tolerance and hospitality toward new ideas is a difficult one, but it has been largely mastered by men of science, and the influence has gone over to the realms of thought. Men are gradually learning the lesson of science and history, and are regarding their own platforms as only stages in the great on-march of opinion.

Another great contribution that science has made to thought, lies in the prominence it has given to the inductive method. It would be a serious error to suppose that *a priori* methods have not played an important part in the advancement of science. Many great conceptions of science of to-day had their origin as speculations, but science has refused to stop with speculations. Using speculations only as suggestive hypotheses, it has passed on to the firm establishment of its doctrines by the accumulation and orderly arrangement of facts of observation and experiment. It took long for science to extricate itself from the Nature Philosophy of the eighteenth century. To the philosophers of that day, the system and methods of nature were things to be explained, *a priori*, on the basis of certain postulates; to the poets they were to be discovered by a sort of divination It is safe to say there will be no more systems of Nature Philosophy proposed by sane men. Its problems have been relegated to the rigid methods of science. There is no question that the fruitfulness of the scientific method has reacted upon almost every branch of learning. We have but to point to the laboratory Psychology and to the statistical methods of Political Science and Sociology as illustrations.

The greatest influence that science has contributed to thought since the time of Copernicus and Newton is that of evolution. Of evolution in itself there is no occasion to speak in this place. The idea of evolution is revolutionizing the thought of the world. We are not here to deny the rise of the historical spirit in many departments of thought near the beginning of this century, but there is no doubt that the spirit has had its support and encouragment in the solid achievements of the evolutionary idea in natural science. No other idea has attracted such universal attention, and has found such wide application and exerted such profound influence in altering the point of view in all departments of thought. It is the greatest discovery of this and perhaps of any century.

How insignificant the world of 100 years ago as compared with that of the present time. The world of the eighteenth century was of recent origin and was stationary. It was inhabited by races of beings that had remained as they were created in the beginning. There was no movement, no progress, only stagnation relieved by the endless repetition of the same unalterably fixed forms. How great the change and how immeasurably extended was the sweep of thought when evolution came and gradually men saw that Nature moves and that our world is the product of changes extending through immeasurably long æons of time; when they saw that incessant change in time and space is the only universal law; that whatever the changes have been in time beyond our ken, the movement has certainly been from the simple to the complex, from the lower to the higher during the periods of time that have left a record.

Man is no exception. He is the offspring of the ages, and his powers and institutions are the result of age-long experience in suffering, labor, struggle and conquest. For such a being, old conceptions and old standards no longer sufficed, and man must be studied anew in his proper setting as a part of nature. His mental powers and ethical perceptions, no less than his physical organization, were seen to be products of evolution and for their right comprehension they must be traced through the lower races of men and the lower animals to their beginnings. There came the conception of the evolution of Society, of the State and Religion, and History was invested with a new meaning and a philosophy, whose teachings must be worked out if we were to have a sound doctrine regarding our present relations, their obligations, and have a vision of the future. The idea has taken firm hold upon learning, and to-day men speak as of commonplaces, about the evolution of language, of the state, of religion; evolution of mind-perceptions, reason, will, conscience and many other things that formerly were regarded as having only an oscillatory movement since the creation of the world.

The restatement of philosophic thought is yet in progress, and it is too early to predict the final result of the influence of sciences, but it is already very great. To take a concrete example, we, who first studied Philosophy as a system about twenty years ago, are surprised to find in the most influential text-book of the day, written by an idealist, Psychology introduced by long discussions of the anatomy and functions of the brain, and the physical basis of habit, and the mind-stuff theory, and to find everywhere physiology insisted upon as the foundation of psychology, and the mental powers discussed on the basis of evolution.

We are surprised to find the terms "Innate Ideas," "Intuitions," "Instincts," omitted entirely, or shorn of their original meanings, and the things they represent referred to purely natural origins. We are surprised to find that right is a relative thing, and conscience is the result of evolution in experience. We find the old problem of egoism versus altruism neatly solved, by making society the unit in ethics, as the species is in biology. The individual is nothing apart from society, its highest interests are his highest interests, and, therefore, the most refined egoism finds itself in the most perfect altruism.

But the glory of science lies no more in its past achievement than in its promise for the future. However difficult the conception, and however impossible it may be to predict the developments of the future, the legitimate inference from the past is, that the developments of the next century will be quite as great as those of the present one. We know that much remains to be done, and we have a right to expect that scientific thought will continue to broaden and deepen, leading ever toward a fuller knowledge of the physical universe and a truer Philosophy.